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Original Paper

Evaluation of C-organic and Total Nitrogen as Soil Fertility Indicators Based on Soil Profile Descriptions in the Surface Soil Layer (Epipedon) in Various Parent Materials

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***Abstract*—Organic carbon and total nitrogen are important indicators in assessing soil fertility because they play a role in nutrient cycles, soil biological activity, and the stability of soil physical and chemical properties. This study aims to evaluate the content of organic carbon, total nitrogen, C/N ratio, and soil pH in the surface soil layer (epipedon) based on differences in parent material in the southern region of Jember, specifically in the subdistricts of Ambulu, Tempurejo, and Wuluhan. This study was conducted from October to December 2025 using a survey method and soil profile description at a depth of 0-25 cm. Soil samples were taken from three types of parent materials: volcanic breccia, limestone breccia, and sand-clay sediment breccia. Laboratory analysis included organic C, total N, and pH H2O, which were then analyzed using descriptive statistics. The results showed that organic C content ranged from 1.11 to 2.96% and total N from 0.03 to 0.41%, while C/N ranged from 6 to 37 with a pH of 6.48 to 7.41. Soil developed from volcanic breccia parent material showed the highest organic C and total N content compared to other parent materials, indicating better soil fertility potential. Soils developed from limestone breccia showed moderate organic C and total N content, while the lowest soil fertility potential was found in soils developed from sandy-clay sedimentary breccia. This indicates that soil parent material is one of the factors that significantly influences the properties of soils in the epipedon layer.**

Keywords*—Organic Carbon, Nitrogen, Epipedon, Parent Material

I. INTRODUCTION

Soil is an important medium for plant growth and the sustainability of agricultural production systems and the environment. The ability of soil to provide water, air, and essential nutrients greatly affects plant growth and beneficial microorganisms in the soil itself. One of the main aspects in determining soil fertility is the chemical properties of the soil, especially those related to soil organic carbon and total nitrogen [1]. These components are not only a source of nutrients for plants but also play a role in forming soil structure, increasing cation exchange capacity and overall water retention. Soil organic carbon content is known as a fundamental indicator of soil fertility and soil function, which is a source of energy for soil biological activity directly related to the nutrient cycle, water cycle and greenhouse gas emissions [2].

Organic carbon is the organic fraction of the total soil composition that comes from plant residues, microbes, and other organisms that have undergone or are undergoing decomposition. The organic matter content of soil can be reflected in the balance between organic matter input and the level of mineralization in the soil profile [3]. High organic carbon values are generally correlated with more fertile soil conditions because they support high biochemical activity and efficient nutrient circulation. Organic matter is influenced by various environmental factors such as vegetation, microbial communities, and physical properties of the soil that support its availability in the soil [4]. Total nitrogen is a primary macro nutrient that determines soil-plant productivity. Nitrogen in the soil mostly comes from the decomposition of organic matter, so the total N content of the soil is often closely related to organic C and the mineralization process. An increase in organic matter is generally followed by an increase in total nitrogen as it decomposes by microbes, which is then converted into a form available to plants through mineralization and nitrification processes [5].

Parent material is the most dominant component of soil in terms of proportion and plays an important role in the transformation of organic matter and physical-chemical processes in soil. The distribution and accumulation of organic matter and total nitrogen in soil profiles can also be determined by parent material through its influence on variations in soil texture, structure, minerals, and chemical reactivity. The amount, stratification, and depth of soil organic matter and total nitrogen are influenced by parent material as well as land use practices such as crop type and land management systems [6]. The surface soil layer (epipedon) is the most active horizon in terms of organic matter change because it is associated with the addition of litter, twigs, and other biomass and reduction due to decomposition and material transfer by surface water flow. Epipedon characteristics are often early indicators of soil productivity potential and response to crop cultivation. Analysis of organic carbon and total nitrogen in

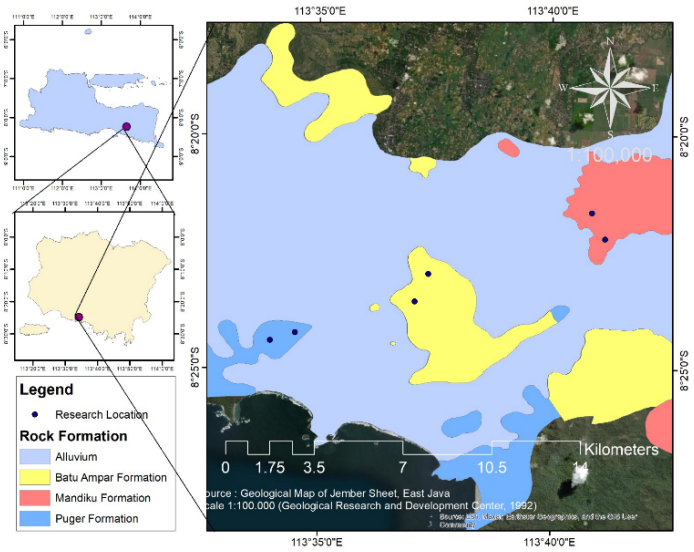


Fig. 1. Research Location Map

TABLE I. RESEARCH LOCATION

Profil	Parent Material	Geographical Location	Elevation (m)
1	Volcanic rock breccia (Tmm)	-8.392586 113.617931	225
2	Volcanic rock breccia (Tmm)	-8.383292 113.622370	295
3	Limestone breccia (Tmp)	-8.407271 113.566407	128
4	Limestone breccia (Tmp)	-8.403631 113.574486	141
5	Sedimentary rock breccia sand-clay (Tomb)	-8.361381 113.681039	200
6	Sedimentary rock breccia sand-clay (Tomb)	-8.369414 113.686195	119

the epipedon provides important information for assessing soil fertility conditions in relation to soil-forming factors such as parent material, climate, and land use history, which are useful in developing wild plants and crops for better land use management [7].

The research location is in Jember Regency, specifically in the southern part of Jember (Ambulu, Tempurejo, and Wuluhan Districts). This research was conducted in an area with three different parent materials in terms of geological formation. Volcanic breccia, which is part of the Mandiku formation, sandstone and claystone interbeds, which are part of the Ampar formation, and the Puger formation, which is reef limestone. Different parent materials allow for variations in soil properties and characteristics due to differences in minerals and weathering processes of the parent materials. The physical and chemical properties of soil, which are one of the indicators of soil fertility, are greatly influenced by soil development processes [8]. These variations in parent material were used to examine their effect on the organic carbon and total nitrogen content in the surface soil layer (epipedon).

II. METHODS

A. Location and Time

This research was conducted from October to December 2025 in the Ambulu, Tempurejo and Wuluhan District, Jember Regency, East Java. The research location was carried out on three parent material formations, namely volcanic breccia, limestone breccia, and sandstone-clay sediment breccia. This research was conducted in the valley and hilltop areas of the southern Jember mountain range.

B. Soil Sampling Strategy

Soil sampling was conducted by observing soil profiles representative of different parent materials under relatively similar land-use conditions. Observation sites were selected to form a lithosequence, thereby minimizing the influence of soil-forming factors other than parent material. Sampling was not based on Land Use Map Units (SPL), but rather on individual pedons considered representative of each parent material. Soil sampling was conducted on the surface soil layer (epipedon). Samples were taken from the surface soil layer (Horizon A) according to the thickness of the horizon found in each profile, with depths ranging from 0–25 cm. The collected soil samples were then placed in plastic bags and labeled with information on the sampling location, pedon code, and parent material type. The samples were subsequently transported to the laboratory for analysis of soil chemical properties.

C. Analysis of Soil chemical Properties in the Laboratory

The collected soil samples were air-dried, crushed, and sieved using a 2-mm sieve before being analyzed in the laboratory. Analysis of soil chemical properties included soil pH, organic carbon (organic C), total nitrogen (total N), and the C/N ratio. Soil pH was measured using a pH meter on a soil suspension in deionized water. Organic carbon content was determined using the Kurmies method, while total nitrogen was analyzed using the Kjeldahl method. The C/N ratio was calculated based on the ratio of organic carbon to total nitrogen obtained from the laboratory analysis results.

TABLE II. SOIL CHEMISTRY ANALYSIS PARAMETERS

No.	Variable	Method
1.	Organic Carbon Analysis	Kurmies
2.	Total N Analysis	Kjeldhal
3.	pH Analysis H_2O	pH Meter

D. Data Processing

The data obtained from the analysis of soil chemical properties, including organic carbon content, total nitrogen, C/N ratio, and soil pH, was then processed and analyzed descriptively for each related parameter. In addition, the data obtained is also presented in the form of statistical graphs to facilitate the interpretation of the relationship between variations in soil parent material and organic carbon content, total nitrogen, and C/N ratio in the topsoil (epipedon). The presentation of data in graph form aims to provide a clearer picture of the distribution patterns and trends in soil parameter values for each parent material.

In addition to descriptive analysis, statistical analysis was conducted to determine the relationships and differences in soil chemical properties based on variations in parent material. Analysis of Variance (ANOVA) was used to test for differences in organic carbon and total nitrogen content in soils derived from different parent materials. Furthermore, Spearman's correlation analysis was used to measure the strength of the relationship between parent material and organic carbon and total nitrogen content, as well as the relationships among the observed soil chemical property parameters. The results of these statistical analyses were used to provide a clearer picture of the influence of parent material on variations in soil chemical properties and the relationships among parameters for each parent material.

Spearman's correlation coefficient is calculated using the following equation [9]:

$$R = \frac{\sum_{i=1}^{n} \left(ri - \overline{R}\right)(Si - \overline{S})}{\left(\sum_{i=1}^{n} (ri - \overline{R})^2 \sum_{i=1}^{n} (si - \overline{S})^2\right)^{1/2}} \quad (1)$$

III. RESULT AND DISCUSSIONS

A. Abbreviations and Acronyms

Parent material is one of the factors that form soil and plays an important role in determining the physical and chemical properties of soil. Differences in parent material will affect the mineral composition, weathering level, and ability of soil to retain and store nutrients and organic matter. Based on research data, the parent materials that form the soil found at the observation site consist of volcanic breccia, limestone breccia, and sand-clay sediment breccia. Sedimentary rocks are rocks formed from previous rocks through physical, chemical, and biological processes. In sedimentary parent materials, soil characteristics are greatly influenced by the composition of the material that has undergone sedimentation because the processes of transportation and deposition determine the distribution of particle size and mineral composition, which in turn influence the physical and chemical properties of the soil [10].

Soil that develops from volcanic breccia parent material is relatively fertile compared to soil derived from other parent materials. Volcanic eruption materials generally have a richer mineral content and high nutrient levels, which greatly supports plant growth. Research conducted by [11] shows that volcanic soil has high fertility potential because it is dominated by easily weathered minerals with a percentage of around 69-89%. The main minerals found are augite (22-42%) and hypersthene (23-58%), which act as reserves of important nutrients such as Mg, Ca, Na, and Fe. In addition, other minerals such as sanidine, hornblende, and tourmaline are also found and contribute other nutrients, such as Potassium (K), Mangan (Mn), and Boron (B).

Breccia limestone is formed from fragments of limestone that have undergone weathering and redeposition. This is caused by the weathering of limestone, which produces calcium ions (Ca^{2+}) as well as carbonate and bicarbonate ions. This process causes the soil pH to tend to be neutral to slightly alkaline, making the availability of nutrients for plants more optimal. The increase in soil pH is related to the presence of base cations (Ca^{2+}) and carbonate anions (CO_3^{2-}) in limestone, which can replace H^+ ions in the soil exchange complex, producing H_2O and CO_2. [12]. The high carbonate content in this parent material not only functions as an inorganic carbon sink and regulator of organic carbon accumulation, but also plays an important role in maintaining soil fertility and helping to reduce environmental contaminants [13].

Conversely, soils formed from sandy-clay breccia parent material have lower fertility. This condition may be due to the coarser soil texture and lower capacity to retain organic matter compared to soils developed from other parent materials. The coarser texture causes organic matter to decompose more easily and be washed out of the soil profile, resulting in lower accumulation of organic carbon and total nitrogen. The amount of organic carbon in heavy (fine) soils rich in clay and silt fractions is significantly higher. Clay-rich soils have a longer turnover time and slower decomposition of organic matter than sandy soils [14].

B. Organic Carbon

Organic carbon is an indicator of how much organic matter is present in the soil. Low organic matter content in a plot of land will affect the physical, chemical, and biological properties of the soil. Soil properties related to organic matter content include aggregate stability, cation exchange capacity, water retention, and soil microorganism activity. Microorganisms utilize organic carbon as a source of energy and for metabolic processes [15]. The analysis results show that the organic carbon content in the surface layer (epipedon) varies significantly between soil profiles, ranging from 1.11% to 2.96%, which is classified as low to moderate. This variation reflects differences in soil-forming factors, particularly organic matter input from vegetation, soil biological activity intensity, and decomposition rates at each location.

The highest organic C content was found in profile 1 at 2.96%, indicating a relatively greater accumulation of organic matter compared to other areas. The high organic C content reflects soil quality that is classified as fertile [16]. In contrast, profile 6 showed the lowest organic C content of 1.11%,

TABLE III. SOIL ANALYSIS RESULT

Profil	Parent Material	Horizon	Depth (cm)	Chemical Properties of Soil			
				Organic Carbon (%)	Total N (%)	C/N Ratio	pH H_2O
1	Volcanic rock breccia (Tmm)	A	0-23	2,96	0,41	7	6,48
2	Volcanic rock breccia (Tmm)	A	0-18	1,56	0,25	6	6,55
3	Limestone breccia (Tmp)	A	0-24	1,49	0,13	11	7,41
4	Limestone breccia (Tmp)	A	0-23	1,49	0,11	13	7,3
5	Sedimentary rock breccia sand-clay (Tomb)	A	0-23	1,40	0,10	14	7,28
6	Sedimentary rock breccia sand-clay (Tomb)	A	0-18	1,11	0,03	37	7,26

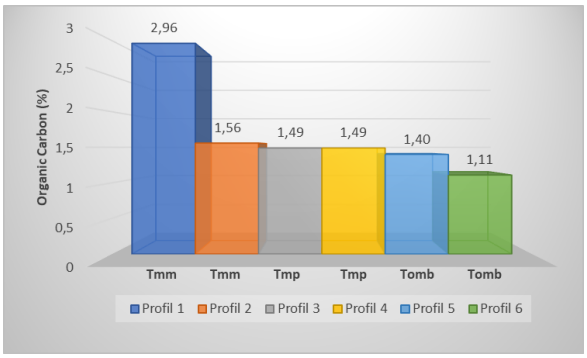


Fig. 2. Organic Carbon (%) Analysis Results

indicating limited accumulation of organic matter or a high rate of decomposition that was not balanced by the addition of new organic matter, thereby potentially reducing the quality and fertility of the soil in that profile. Organic matter is closely related to the availability of nutrients. In addition, soil organic matter plays a crucial role in regulating the mobility, solubility, and absorption of metal elements by plants through the chelation mechanism. This chelation process functions as a natural protection that prevents the precipitation of nutrients, so that their availability to plants is maintained [17].

Differences in organic carbon content across each soil profile are thought to be influenced by differences in the parent material from which the soil developed. Soils derived from volcanic breccia (Tmm) generally contain minerals such as plagioclase, pyroxene, hornblende, and feldspar, which are prone to weathering. This weathering process releases various nutrients, such as calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na), thereby enhancing the soil's chemical fertility [18]. These conditions create a more favorable environment for vegetation growth. Well-established vegetation produces larger amounts of leaf litter, twigs, and root biomass. After decomposition, this biomass becomes the primary source of soil organic matter; consequently, the organic carbon content in soils derived from volcanic breccia tends to be higher [19].

Unlike volcanic breccia, soil derived from limestone breccia (Tmp) is dominated by the minerals calcite ($CaCO_3$) and dolomite ($CaMg(CO_3)_2$), which cause the soil pH to tend toward neutral to slightly alkaline. Although these minerals are sources of calcium and magnesium, their high carbonate content can reduce the availability of certain nutrients particularly phosphorus and micronutrients such as Fe, Zn, and Mn through adsorption and precipitation, resulting in vegetation growth and organic matter accumulation that are not as optimal as in soils derived from volcanic rock [20]. Meanwhile, soils derived from sandy-clay sedimentary breccia (Tomb) are generally dominated by quartz and clay minerals such as kaolinite, illite, and smectite. The dominance of quartz, which is relatively resistant to weathering, results in a slower release of nutrients, leading to relatively lower soil fertility. These conditions inhibit vegetation growth, reduce biomass production, and ultimately result in lower accumulation of organic carbon in the soil compared to soils developed from volcanic rock breccia [21]. These findings are consistent with the results of this study, in which soils developed from volcanic rock breccia (profiles 1-2) have higher organic carbon content than soils developed from limestone breccia (profiles 3-4) and sandy-clay sedimentary rock breccia (profiles 5-6). This indicates that differences in parent material contribute to variations in soil chemical properties, which in turn influence vegetation growth and organic carbon accumulation in each profile.

C. Nitrogen

Nitrogen is an essential macro nutrient that plants need in large quantities. Nitrogen is generally absorbed by plants in the form of ammonium and nitrate ions. The negative charge on nitrate ions causes this nitrogen element to remain in the soil solution and have fairly high mobility, making it easy to reach the root surface. However, high mobility also makes nitrate more susceptible to leaching, especially in soils with high rainfall, thereby reducing its availability [22]. Conversely, ammonium ions (NH4+), which are positively charged, tend to be adsorbed onto soil colloids and can be absorbed by plants through cation exchange mechanisms, making them relatively stable and less prone to loss due to leaching [23].

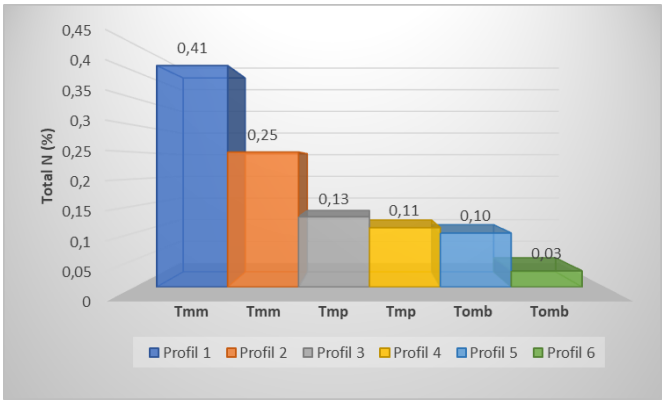


Fig. 3. Total Nitrogen (%) Analysis Results

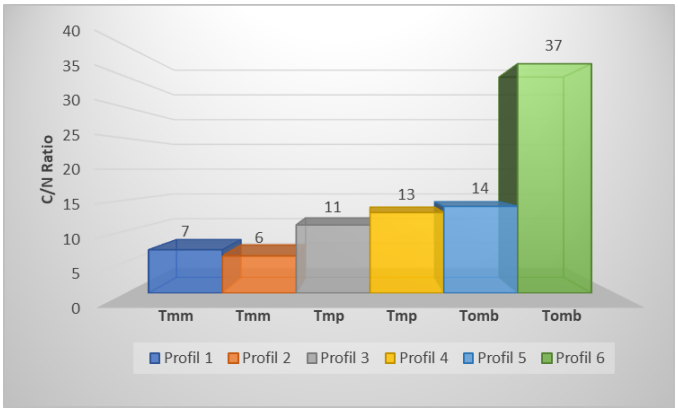


Fig. 4. C/N Ratio

The results of the total N analysis of the surface layer (epipedon) show variations between profiles, ranging from 0.03% to 0.41%, which is classified as very low to moderate. This variation indicates differences in soil characteristics in each profile, mainly due to organic matter content, soil biological activity, and the land management system applied [24]. The highest total N value was found in Profile 1 at 0.41%, reflecting soil conditions with moderate nitrogen content and relatively better conditions. Higher nitrogen content is generally closely related to the accumulation of organic matter, because most nitrogen is stored in organic form and is available to plants after undergoing mineralization [25]. Conversely, Profile 6 had the lowest total N value of 0.03%, indicating that the nitrogen content in the soil was very low. Very low nitrogen conditions can be influenced by low organic matter input, high nitrogen loss due to leaching, or an imbalance between decomposition and nitrogen supply [26].

Differences in total nitrogen content among soil profiles are influenced by the characteristics of the parent material, which govern the weathering process and soil development. During weathering, each parent material produces distinct physical and chemical soil characteristics, thereby forming a microenvironment that influences the activity of soil microorganisms [27], [28]. These conditions such as soil pH, moisture, and organic carbon content play a crucial role in determining the abundance of nitrogen-fixing microorganisms [29]. The activity of these microorganisms supports the process of biological nitrogen fixation, thereby increasing nitrogen availability in the soil [30].

The results of the study show that soil derived from volcanic breccia (Tmm) has a higher total nitrogen content than soil derived from limestone breccia (Tmp) or sandy clay sediment breccia (Tomb). Differences in parent material result in distinct soil development through weathering processes, thereby creating environmental conditions that influence vegetation growth and soil microorganism activity. The accumulation of litter from vegetation increases the organic matter content, which serves as an energy source for soil microorganisms, including nitrogen-fixing bacteria that play a role in the process of biological nitrogen fixation [30], [31]. Increased accumulation of organic matter also contributes to higher total nitrogen content because most soil nitrogen is stored in the form of organic compounds derived from plant residues, such as proteins, peptides, and amino acids. Through decomposition and mineralization, these organic compounds are converted into forms of nitrogen available to plants, thereby increasing soil nitrogen reserves [32]. In contrast, soils derived from limestone breccia and sandy clay sediment breccia have environments that are less conducive to microbial activity; consequently, nitrogen input through organic matter decomposition and biological fixation is lower, as reflected in the lower total nitrogen content in profiles 3 through 6 [29].

D. C/N Ratio

The C/N ratio is the ratio between the organic carbon and total nitrogen content in the soil. The C/N ratio plays an important role in the provision of nutrients in the soil.

An ideal C/N ratio indicates a good balance between decomposed organic matter and nitrogen availability for plants [33]. In soils with a low C/N ratio, excess nitrogen (N) can interfere with microbial activity. Conversely, a high C/N ratio causes N deficiency, thereby inhibiting plant growth and making plants more susceptible to pathogens. Research by [34] provides evidence of the role of soil C/N ratio in shaping plant responses to root-knot nematode infection, emphasizing the importance of C/N ratio balance in maintaining optimal microbial activity, preventing nutrient deficiencies, and enhancing overall plant resilience.

Based on the analysis data, the C/N ratio in the surface soil layer (epipedon) shows variation between profiles, ranging from 6 to 37. Profiles 1 and 2 have relatively low C/N ratios. A low ratio reflects a balance of carbon and nitrogen that supports optimal mineralization, resulting in a relatively high potential for nitrogen availability to plants. This condition is in line with the high total nitrogen content in profile 1 of 0.41% and profile 2 of 0.25%, which indicates that some of the nitrogen is in a form that is easier to mineralize. Profiles 3, 4, and 5 show moderate C/N ratios, ranging from 11 to 14. In contrast, profile 6 shows a very high C/N ratio of 37. A high C/N ratio indicates low nitrogen availability in the soil. This shows that a high C/N ratio means a larger fraction of carbon compared to nitrogen as a substrate for microbial activity in the fermentation of organic matter. The balance of these two parameters determines the efficiency of the nutrient cycle and soil productivity [35].

E. *Carbon and Nitrogen Their Relationship with Parent Material*

Parent material is a soil-forming factor that greatly influences soil chemical characteristics, including organic carbon and total nitrogen content. Differences in mineral composition, weathering levels, and soil physical properties influence the accumulation of organic matter and the nitrogen cycle in soil. Based on the results of the study, there are variations in organic carbon and total nitrogen content in soils developed from sedimentary parent materials, including volcanic breccia, limestone breccia, and sand-clay breccia. These variations indicate that parent material plays an important role in determining the fertility level of surface soil (epipedon).

Soil developed from volcanic breccia parent material shows higher organic carbon and total nitrogen content compared to other parent materials. In profiles originating from volcanic breccia parent material, organic carbon content reaches 2.96% with total nitrogen at 0.41%. These conditions indicate that soil originating from volcanic breccia parent material has a good ability to accumulate organic matter. In soil formed from limestone breccia parent material, the organic carbon and total nitrogen content tends to be in the moderate category. The organic C content is 1.49%, while total nitrogen ranges from 0.11% to 0.13%. This condition is influenced by the properties of limestone breccia parent material, which is dominated by carbonate rocks composed of calcium carbonate ($CaCO_3$) compounds. Soils that develop on limestone have relatively good chemical properties for plant growth, resulting in high carbon accumulation. Based on research by [36], exchangeable Ca and Mg have a strong influence on soil organic carbon accumulation, especially in karst soils that develop from carbonate rocks. In addition, the results also show that soils derived from limestone breccia parent material tend to have higher pH levels. The dissolution of CO_2 can form carbonic acid, which produces H^+ ions, causing a decrease in pH. However, in soils containing carbonate, the weathering of $CaCO_3$ can release Ca^{2+} and HCO_3^- ions, which play a role in neutralizing H^+ ions through the carbonate buffer system in the soil profile [37].

Soil developed from sandy-clay sediment breccia parent material shows lower organic carbon and total nitrogen content compared to other parent materials. In soil profiles originating from sandy-clay breccia parent material, organic carbon content was recorded at 1.11% with total nitrogen at 0.03%. The low organic carbon and nitrogen content in these soils is related to soil texture, where soils derived from sandy-clay sedimentary breccia parent material have a relatively coarser texture, limiting the soil's ability to retain and preserve organic matter [38]. A sandier texture causes organic matter to be more easily leached. In addition, the relationship between organic carbon and total nitrogen in each parent material shows a fairly significant pattern, where soils with higher organic carbon content tend to have higher total nitrogen content as well. The dynamics of SOC are intimately tied with soil nitrogen (N) cycle, as the decomposition and formation of SOM demand SOC as energy supply for microbial activity and N for the differentiation and development of microbial and plant tissues [39]. The low amount of total N is due to the low organic matter content of the soil, which affects the availability of organic N in the soil [40].

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
organiccarbon	Between Groups	1,105	2	,553	1,622	,333
	Within Groups	1,022	3	,341		
	Total	2,127	5			
totalnitrogen	Between Groups	,078	2	,039	7,595	,067
	Within Groups	,015	3	,005		
	Total	,094	5			

F. *Statistical Analysis of the Correlation Between Soil Chemical Properties and Various Parent Materials*

The results of the One-Way Analysis of Variance (ANOVA) test showed that the type of parent material did not have a significant effect on organic carbon content ($F = 1.622$; $p = 0.333$) or total soil nitrogen ($F = 7.595$; $p = 0.067$) at a 5% significance level. These p-values indicate that differences in parent material specifically volcanic rock breccia (Tmm), limestone breccia (Tmp), and sandy-clay sedimentary rock breccia (Tomb) did not result in significant differences in organic carbon or total nitrogen content in the A horizon. These findings suggest that variations in these two soil chemical properties result more from the interaction of various soil-forming factors than from the sole influence of parent material. [41] this explains that the distribution of Soil Organic Carbon (SOC) is controlled not only by parent material but also by a combination of soil-forming factors, particularly climate, organisms, topography, and land use. Therefore, the contribution of parent material to organic carbon content in surface soil is often indirect because it has been modified by ongoing pedogenic processes.

Although no significant differences were found based on the ANOVA test, the research data indicate a trend that soils derived from volcanic rock breccia have higher organic carbon (1.56-2.96%) and total nitrogen (0.25-0.41%) contents compared to soils derived from limestone breccia or sandy-clay sedimentary rock breccia. These differences were not large enough to be statistically significant. Nevertheless, this pattern indicates a tendency for different responses among the parent materials. In the A horizon, organic carbon accumulation is influenced more by litter input, root system development, and microbial activity than by the characteristics of the parent lithology. The ongoing decomposition process produces organic matter that is subsequently stabilized through the formation of aggregates and organo-mineral complexes. [42] explains that the stabilization of soil organic matter is influenced by aggregate formation and the association between organic matter and soil minerals, which protects carbon from decomposition. This is believed to be one of the reasons why no significant differences in organic carbon content were found among the parent materials.

Unlike organic carbon, the significance value for total nitrogen ($p = 0.067$) was closer to the level of significance, indicating a tendency for nitrogen to be more responsive to differences in parent material. Descriptively, the total nitrogen content in soils developed from volcanic breccia ranged from 0.25-0.41%, whereas in soils developed from sandy-clay

Correlations

			organiccarbon	totalnitrogen	parent_code
Spearman's rho	organiccarbon	Correlation Coefficient	1,000	,986**	,485
		Sig. (2-tailed)	.	,000	,329
		N	6	6	6
	totalnitrogen	Correlation Coefficient	,986**	1,000	,478
		Sig. (2-tailed)	,000	.	,338
		N	6	6	6
	parent_code	Correlation Coefficient	,485	,478	1,000
		Sig. (2-tailed)	,329	,338	.
		N	6	6	6

**. Correlation is significant at the 0.01 level (2-tailed).

sedimentary breccia, it ranged only from 0.03-0.10%. This difference suggests that soils developed from volcanic parent material tend to retain nitrogen better than those derived from sedimentary parent material. According to [43], mineralogical changes during soil development play a crucial role in the formation of organo-mineral complexes that control carbon and nitrogen retention. However, the relatively limited number of soil profiles means that this trend cannot yet be statistically proven through an ANOVA test.

These ANOVA results were supported by a Spearman correlation analysis, which revealed a very strong positive relationship between organic carbon content and total nitrogen content ($r = 0.986$; $p < 0.001$). This relationship indicates that an increase in organic carbon content is accompanied by an increase in total nitrogen content, as most of the nitrogen is stored in the soil's organic matter fraction. Although differences in parent material do not have a significant effect on total nitrogen content, parent material still plays a crucial role as a soil-forming factor that controls the development of soil characteristics. Differences in mineral composition and weathering levels among parent materials result in variations in the physical, chemical, and mineralogical properties of the soil, such as texture, pH, cation exchange capacity, and nutrient availability. These variations in characteristics subsequently influence the soil's ability to support vegetation growth, soil organism activity, and the rate of organic matter decomposition. In parent materials capable of forming soils with more fertile conditions and better support for vegetation growth, litter and root biomass inputs tend to be higher, leading to increased organic matter accumulation. Since most nitrogen is present in soil organic matter, this increase in organic matter accumulation is accompanied by an increase in total nitrogen content. Therefore, the influence of parent material on nitrogen content at the study site is primarily indirect, mediated through the formation of soil characteristics and the regulation of biological processes occurring within the soil, as reflected by the very strong correlation between organic carbon and total nitrogen content.

IV. CONCLUTIONS

The results of this study indicate that soil chemical properties in the surface soil layer (epipedon), including organic carbon, total nitrogen, C/N ratio, and pH, vary among soils developed from different parent materials. Soils derived from volcanic breccia exhibited the highest organic carbon (2.96%) and total nitrogen (0.41%) contents, indicating a greater potential for soil fertility than soils developed from limestone breccia and sandy-clay sedimentary breccia. Limestone breccia soils showed intermediate values of organic carbon (1.49%) and total nitrogen (0.11-0.13%), whereas soils developed from sandy-clay sedimentary breccia had the lowest organic carbon (1.11%) and total nitrogen (0.03%) contents.

The One-Way ANOVA indicated that differences in parent material did not significantly affect organic carbon or total nitrogen contents in the epipedon at the 5% significance level. Nevertheless, descriptive results consistently showed that volcanic breccia tended to produce soils with higher organic carbon and total nitrogen than the other parent materials. This suggests that the influence of parent material on soil fertility is primarily indirect through its control over soil physical, chemical, and mineralogical characteristics, which subsequently affect vegetation development, soil biological activity, organic matter accumulation, and nitrogen cycling. Spearman correlation analysis revealed a very strong positive relationship between organic carbon and total nitrogen ($r = 0.986$; $p < 0.001$), indicating that increases in organic carbon are accompanied by increases in total nitrogen because most soil nitrogen is stored in the organic matter fraction. Therefore, organic matter accumulation plays a more important role in controlling nitrogen reserves in the epipedon than the direct influence of parent material.

References

[1] A. Chowdhuri et al., "Optimizing soil fertility and climate resilience: Superiority of organic farming in enhancing carbon sequestration and nitrogen supply," J. Environ. Manage., vol. 393, p. 127131, Oct. 2025, doi: 10.1016/j.jenvman.2025.127131.

[2] D. Liptzin et al., "An evaluation of carbon indicators of soil health in long-term agricultural experiments," Soil Biol. Biochem., vol. 172, p. 108708, Sep. 2022, doi: 10.1016/j.soilbio.2022.108708.

[3] V. S. Freitas et al., "Soil organic matter dynamics and soil carbon stocks from tropical and sub-tropical areas under no-till: An on-farm research," CATENA, vol. 247, p. 108491, Dec. 2024, doi: 10.1016/j.catena.2024.108491.

[4] Y.-Z. Li et al., "Toward soil carbon storage: The influence of parent material and vegetation on profile-scale microbial community structure and necromass accumulation," Soil Biol. Biochem., vol. 193, p. 109399, Jun. 2024, doi: 10.1016/j.soilbio.2024.109399.

[5] D. Meng et al., "Progress on the Effect of Nitrogen on Transformation of Soil Organic Carbon," Processes, vol. 10, no. 11, p. 2425, Nov. 2022, doi: 10.3390/pr10112425.

[6] X. Zhang, M.-J. Li, C. Yang, L.-Q. Zhan, W. Wu, and H.-B. Liu, "The stratification of soil organic carbon and total nitrogen affected by parent material and cropping system," CATENA, vol. 210, p. 105898, Mar. 2022, doi: 10.1016/j.catena.2021.105898.

[7] C. Paltineanu et al., "Soil organic carbon and total nitrogen stocks related to land use and basic environmental properties − assessment of soil carbon sequestration potential in different ecosystems," CATENA, vol. 246, p. 108435, Nov. 2024, doi: 10.1016/j.catena.2024.108435.

[8] H. Yulina, M. Arifin, R. Devnita, M. R. Djuwansah, and F. Raidasari, "The relationship between soil properties in pedogenesis dynamics: A study of pedons on slopes and basins," SAINS TANAH - J. Soil Sci. Agroclimatol., vol. 22, no. 2, p. 500, Dec. 2025, doi: 10.20961/stjssa.v22i2.109149.

[9] M. Stephanou and M. Varughese, "Sequential estimation of Spearman rank correlation using Hermite series estimators," J. Multivar. Anal., vol. 186, p. 104783, Nov. 2021, doi: 10.1016/j.jmva.2021.104783.

[10] A. P. B. Lima, A. V. Inda, Y. L. Zinn, E. R. da Silva, and P. C. do Nascimento, "Soil formation and properties along a sedimentary lithosequence in the ecotonal Cerrados of Mato

Grosso, Brazil," CATENA, vol. 219, p. 106599, Dec. 2022, doi: 10.1016/j.catena.2022.106599.

[11] R. Q. Muslim, D. T. Suryaningtyas, G. M. Subiksa, and B. Mulyanto, "KARAKTERISTIK MINERAL PASIR TANAH VULKANIK SEBAGAI CADANGAN HARA UNTUK MENINGKATKAN PRODUKTIVITAS TANAH," 2024.

[12] A. O. Peter, O. Martins, and N. M. Francis, "Effects of lime and fertilizer on soil properties and maize yields in acid soils of Western Kenya," African J. Agric. Res., vol. 13, no. 13, pp. 657–663, Mar. 2018, doi: 10.5897/AJAR2018.13066.

[13] W. Du et al., "Carbonate weakens the interactions between potassium and calcareous soil," RSC Adv., vol. 14, no. 48, pp. 35275–35285, 2024, doi: 10.1039/D4RA05988C.

[14] S. Kuśmierz, M. Skowrońska, P. Tkaczyk, W. Lipiński, and J. Mielniczuk, "Soil Organic Carbon and Mineral Nitrogen Contents in Soils as Affected by Their pH, Texture and Fertilization," Agronomy, vol. 13, no. 1, p. 267, Jan. 2023, doi: 10.3390/agronomy13010267.

[15] Y. Y. Bolly and G. O. Apelabi, "ANALISIS KANDUNGAN BAHAN ORGANIK TANAH SAWAH SEBAGAI UPAYA PENILAIAN KESUBURAN TANAH DI DESA MAGEPANDA KECAMATAN MAGEPANDA KABUPATEN SIKKA," AGRICA, vol. 15, no. 1, pp. 26–32, Aug. 2022, doi: 10.37478/agr.v15i1.1919.

[16] F. Lesthyana, R. Santi, and R. Apriyadi, "Pengaruh C-organik Tanah terhadap Keanekearagaman Mesofauna di Areal Perkebunan Karet (Hevea brasiliensis) Desa Kemuja Bangka," Natl. Multidiscip. Sci., vol. 2, no. 3, pp. 129–140, May 2023, doi: 10.32528/nms.v2i3.276.

[17] E. N. Ginting, "PENTINGNYA BAHAN ORGANIK UNTUK MENINGKATKAN EFISIENSI DAN EFEKTIVITAS PEMUPUKAN DI PERKEBUNAN KELAPA SAWIT," War. Pus. Penelit. Kelapa Sawit, vol. 25, no. 3, pp. 139–154, Oct. 2020, doi: 10.22302/iopri.war.warta.v25i3.38.

[18] S. Purwanto, R. A. Gani, and E. Suryani, "Characteristics of Ultisols derived from basaltic andesite materials and their association with old volcanic landforms in Indonesia," SAINS TANAH - J. Soil Sci. Agroclimatol., vol. 17, no. 2, p. 135, Dec. 2020, doi: 10.20961/stjssa.v17i2.38301.

[19] S. G. Wilson, J.-J. Lambert, M. Nanzyo, and R. A. Dahlgren, "Soil genesis and mineralogy across a volcanic lithosequence," Geoderma, vol. 285, pp. 301–312, Jan. 2017, doi: 10.1016/j.geoderma.2016.09.013.

[20] Y. Geng et al., "Phosphorus biogeochemistry regulated by carbonates in soil," Environ. Res., vol. 214, p. 113894, Nov. 2022, doi: 10.1016/j.envres.2022.113894.

[21] S. Yang, B. Jansen, K. Kalbitz, F. O. Chunga Castro, R. L. van Hall, and E. L. H. Cammeraat, "Lithology controlled soil organic carbon stabilization in an alpine grassland of the Peruvian Andes," Environ. Earth Sci., vol. 79, no. 2, p. 66, Jan. 2020, doi: 10.1007/s12665-019-8796-9.

[22] L. Raus and D. Bolohan, "ASSESSMENT OF THE EFFECTS OF SLOW-RELEASE FERTILIZERS APPLICATION OVER THE AMOUNT OF NITROGEN LEACHED AND OF THE DEVELOPMENT OF WINTER WHEAT PLANTS IN CONTROLLED CLIMATE CONDITIONS," 2025.

[23] C. Thananseyan, S. Kumari, M. Ariyaratne, and L. Suriyagoda, "Neem, mahua and sesame seed cakes, and tamarind husk powder on improving nitrogen-use efficiency in rice," Int. J. Recycl. Org. Waste Agric., 2025, doi: 10.57647/ijrowa.2026.17962.

[24] Y. A. Susetyo, A. D. Sigar, B. H. Simanjuntak, A. W. Setiawan, and D. Banjarnahor, "Hubungan Praktik Budidaya di Berbagai Perkebunan di Sub-Daerah Aliran Sungai Tuntang Provinsi Jawa Tengah terhadap Karbon Organik Tanah," AGRIUM J. Ilmu Pertan., Oct. 2025, doi: 10.30596/agrium.v28i2.24179.

[25] U. Fadilla, R. W. Nusantara, and R. Manurung, "ANALISIS BEBERAPA SIFAT KIMIA TANAH PADA DUA MACAM PENGGUNAAN LAHAN DI SUNGAI KAKAP, KABUPATEN KUBU RAYA, KALIMANTAN BARAT," J. Tanah dan Sumberd. Lahan, vol. 11, no. 1, pp. 247–252, Jan. 2024, doi: 10.21776/ub.jtsl.2024.011.1.26.

[26] P. Pebriandi et al., "Analysis of the Physical and Chemical Properties of Soil in the Riau University Arboretum," J. Biol. Trop., vol. 26, no. 1, pp. 630–637, Feb. 2026, doi: 10.29303/jbt.v26i1.10805.

[27] H. O. Beckford, C. Chang, and H. Ji, "Elemental Behavior during Weathering and Pedogenesis of Clay-Rich Red Soils Developed in Different Lithologies in Java–Madura and Sulawesi in Indonesia," Sustainability, vol. 15, no. 6, p. 4936, Mar. 2023, doi: 10.3390/su15064936.

[28] C. Li et al., "Effects of nitrogen fertilizers on the bacterial community diversity and the weathering of purple mudstone in Southwest China," Front. Microbiol., vol. 14, Jun. 2023, doi: 10.3389/fmicb.2023.1164826.

[29] Y. Hao, H. Liu, J. Li, and L. Mu, "Environmental tipping points for global soil nitrogen-fixing microorganisms," iScience, vol. 28, no. 1, p. 111634, Jan. 2025, doi: 10.1016/j.isci.2024.111634.

[30] S.-K. Sepp et al., "Global diversity and distribution of nitrogen-fixing bacteria in the soil," Front. Plant Sci., vol. 14, Jan. 2023, doi: 10.3389/fpls.2023.1100235.

[31] X. Wang et al., "Effects of fertilizer application on the bacterial community and weathering characteristics of typical purple parent rocks," Front. Microbiol., vol. 15, Jan. 2025, doi: 10.3389/fmicb.2024.1514646.

[32] S. Farzadfar, J. D. Knight, and K. A. Congreves, "Soil organic nitrogen: an overlooked but potentially significant contribution to crop nutrition," Plant Soil, vol. 462, no. 1–2, pp. 7–23, May 2021, doi: 10.1007/s11104-021-04860-w.

[33] T. Nopsagiarti, M. Anugrah Saputri, and T. Putri Refiani, "ANALISIS pH, C-ORGANIK, N-TOTAL DAN RASIO C/N TANAH LAHAN PERKEBUNAN KELAPA SAWIT DI DESA LOGAS KABUPATEN KUANTAN SINGINGI," J. Agro Indragiri, vol. 10, no. 2, pp. 21–26, Jul. 2025, doi: 10.32520/jai.v10i2.4507.

[34] Y. Li and Y. Li, "Nitrogen addition enhances soil carbon and nutrient dynamics in Chinese croplands: a machine learning and nationwide synthesis," Carbon Balance Manag., vol. 20, no. 1, p. 15, Jun. 2025, doi: 10.1186/s13021-025-00305-4.

[35] J. Li, S. La, M. Song, L. Gao, and Y. Tian, "Evidence for the role of soil C/N ratio in shaping plant responses to root-knot nematode infection," J. Adv. Res., vol. 79, pp. 51–60, Jan. 2026, doi: 10.1016/j.jare.2025.03.036.

[36] L. Yang, P. Luo, L. Wen, and D. Li, "Soil organic carbon accumulation during post-agricultural succession in a karst area, southwest China," Sci. Rep., vol. 6, no. 1, p. 37118, Nov. 2016, doi: 10.1038/srep37118.

[37] A. Ali, U. Taura, S. Al Khamisi, Z. A. Rehan, A. Al Alawi, and A. Al-Rashidi, "Enhanced weathering of lizardite-rich sand in seawater: Effects of pH and CO2 pressure on carbonate formation for climate change mitigation," Dec. 24, 2025. doi: 10.21203/rs.3.rs-8275782/v1.

[38] M. Spohn and J. Stendahl, "Soil carbon and nitrogen contents in forest soils are related to soil texture in interaction with pH and metal cations," Geoderma, vol. 441, p. 116746, Jan. 2024, doi: 10.1016/j.geoderma.2023.116746.

[39] H. Jing et al., "Total nitrogen levels as a key constraint on soil organic carbon stocks across Australian agricultural soils," Environ. Res., vol. 279, p. 121825, Aug. 2025, doi: 10.1016/j.envres.2025.121825.

[40] D. Triadiawarman, "Analisis Kandungan C-Organik dan Nitrogen di Areal Tanaman Lai (Durio kutejensis) di Desa Peridan Kecamatan Sangkulirang Kabupaten Kutai Timur," J. Pertan. Terpadu, vol. 5, no. 1, pp. 98–104, Jun. 2017, doi: 10.36084/jpt..v5i1.119.

[41] Y. Xia, K. McSweeney, and M. M. Wander, "Digital Mapping of Agricultural Soil Organic Carbon Using Soil Forming Factors: A Review of Current Efforts at the Regional and National Scales," Front. Soil Sci., vol. 2, Jul. 2022, doi: 10.3389/fsoil.2022.890437.

[42] J. M. Lavallee, J. L. Soong, and M. F. Cotrufo, "Conceptualizing soil organic matter into particulate and mineral-associated forms to address global change in the 21st century," Glob. Chang. Biol., vol. 26, no. 1, pp. 261–273, Jan. 2020, doi: 10.1111/gcb.14859.

[43] C. R. Lawrence, M. S. Schulz, C. A. Masiello, O. A. Chadwick, and J. W. Harden, "The trajectory of soil development and its relationship to soil carbon dynamics," Geoderma, vol. 403, p. 115378, Dec. 2021, doi: 10.1016/j.geoderma.2021.115378.